Transport Of Optically Active Particles From The Surface Mixed Layer: Losses Due To Grazing And Focculation During The Chalk-Ex Study

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LONG-TERMS GOALS

To determine the mass balance of optically active particles within the surface boundary layer and to identify processes responsible for their redistribution.

OBJECTIVES

1) To perform manipulative experiments in which a known quantity of optically active $CaCO_3$ particles are introduced into the surface mixed layer, and tracked over time and space. This approach effectively removes uncertainty in the production term of the mass balance equation.

2) To quantify the loss from the mixed layer of optically active particles due to grazing and aggregation.

APPROACH

In addition to the work by Dam and McManus, there is close collaboration with Drs. W.M. Balch and C. Pilskaln (Bigelow Lab for Ocean Sciences/Optical and vertical flux studies) and Dr. A. Pluddemann (WHOI/ physical studies). Their work is not included in this report.

In June 2003, we participated in a 10-day cruise in the Gulf of Maine and the slope waters in the Western North Atlantic Ocean. During the cruise, we participated in the deployment of two chalk patches, one in the Gulf of Maine, and another in a station 120 nm southeast of Nantucket (the Southern site) and conducted experiments to investigate the loss of chalk due to grazing and aggregation.

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WORK COMPLETED

Since last year's report, we presented results of the 2001 cruise at the Fall 2002 AGU meeting (Balch et al. 2002, Dam et al. 2002, McManus et al. 2002). Here we report results from the 2003 cruise.

Grazing. We conducted seven grazing experiments as in Landry and Calbet (1999). The experiments were designed to look for evidence of microzooplankton grazing (removal of small particles in the <200 μm treatment) and either top-down control by mesozooplankton (small particles increase as mesozooplankton concentration increases) or direct mesozooplankton removal of particles (small particles decrease with increasing mesozooplankton concentration). Abundance of chalk-sized particles (1-5 μm) was measured with an Elzone particle counter at initial and final (c. 20h) experimental times. For all treatments, one-liter polycarbonate bottles were filled with water pre-screened through 200 μm mesh by reverse flow, amended with chalk particles. Two replicates served as controls (no zooplankton additions). These controls yield the net growth rate of particles in the absence of zooplankton, and thus represent the removal effects by microzooplankton. The treatment was addition of mesozooplankton in successively greater multiples of the natural abundance (three additions, three replicates for each addition). We also had formalin-killed controls in the < 200 μm fraction to account for abiotically-induced changes in particle concentration during the experiments. Because the particle counter cannot distinguish chalk particles from other particles, we also counted chalk particles directly with a microscope equipped with polarized light.

Flocculation. During the same cruise we measured the flocculation rates of particle assemblages, in water from the chalk patches, in Couette devices (Drapeau et al., 1994, Dam and Drapeau, 1995) by monitoring the changes in particle size with time. Measurements were done on seven separate occasions in triplicate incubations lasting approx. 500 minutes. The shear rate in the Coutte devices was 6 s^{-1}. We employed two kinds of devices to measure particle size—an electric impedance device (ElZONE 280 particle counter) and a laser counter (GALAI). Both of these devices can resolve particles as small as 0.5 μm. The chalk particle size ranged from 0.7-4 μm, with a mean size of 1.5 μm.

RESULTS

Grazing. Figure 1 shows examples of the experiments for the two patch deployment stations. In both cases, there was a clear top-down effect of mesozooplankton on small particles. In terms of the mass balance of small particles, our results suggest that the presence of mesozooplankton, by relaxing the ingestion rate of microzooplankton on small particles, reduces the loss rate of these particles from the water column. This role, however, is not independent of location. The slope of the regression for the oligotrophic southern site is an order of magnitude larger than for the Gulf of Maine site. Hence, the top down effect is much stronger in the oligotrophic waters.

We observed different results when we considered only chalk particle losses (Fig. 2). There was no relationship (i.e., regression slope was not significantly different from zero) between chalk particle change and mesozooplankton abundance. Because the intercept of the graphs, which represent chalk loss due to microzooplankton ingestion and other abiotic processes, was not different from the formalin-killed controls, we conclude that microzooplankton did not ingest chalk particles. These results indicate that grazing is not a loss term for chalk particles. These results explain why a chalk signal was not detected in fecal pellets collected in sediment traps during the 2001 cruise (Pilskaln et al. 2002).

The top-down effect of mesozooplankton on the small non-chalk particle has potential consequences for the mass balance of the chalk particles. Because mesozooplankton reduce the loss of non-chalk particles, these particles are then available to collide with chalk particles, leading to enhanced flocculation, and subsequent sinking a process that could be a significant loss term of particles from the mixed layer.
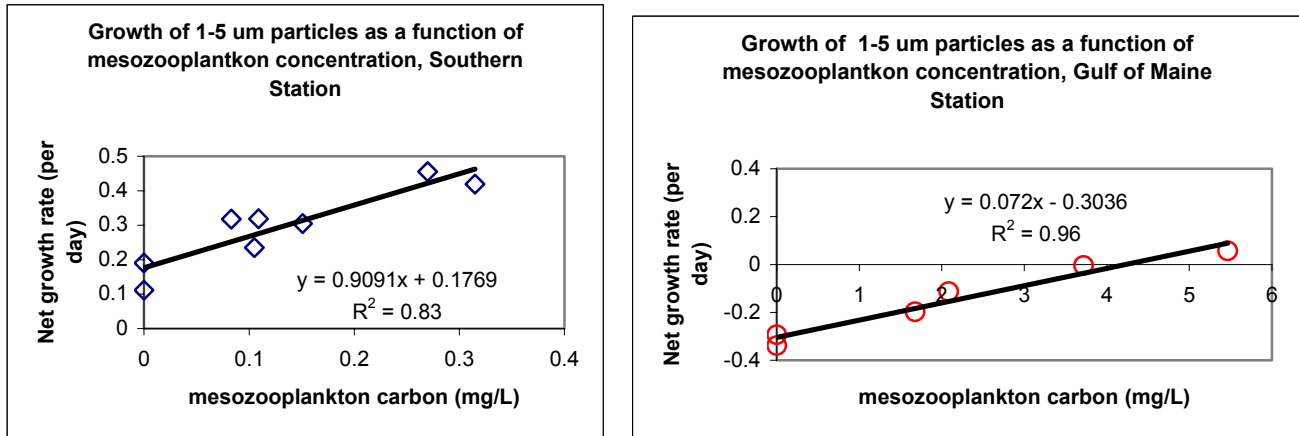

Figure 1. Net daily growth of 1-5 μm particles versus mesozooplankton concentration (expressed as mg carbon/liter) at the southern station (left) and Gulf of Maine station (right). The intercept indicates the net growth rate (particle growth – loss due to microzooplankton grazing). Here we observe that as the relative abundance of mesozooplankton increases, the net particle growth rate also increases. The results are consistent with the hypothesis of mesozooplankton top-down effects on small particles.
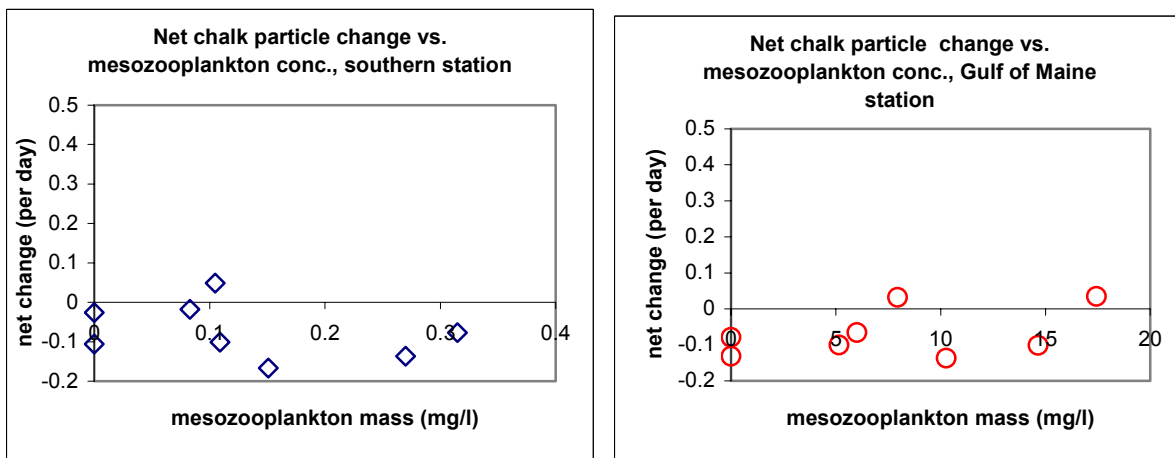

Figure 2. Net daily change of chalk particles versus mesozooplankton concentration (expressed as dry mass/liter) at the southern station (left) and Gulf of Maine station (right). The net change of chalk particles is independent of mesozooplankton concentration. The intercept in the graphs is not significantly different from formalin-killed controls. These results indicate that microzooplankton and mesozooplankton do not consume chalk particles.

Flocculation. The results of the June 2003 cruise were essentially identical to those of the November 2001 cruise. Fig. 3 shows examples of results of the flocculation experiments. Experiment 1 took place prior to the deployment of the chalk, but with water amended with chalk. Experiment 2 took place three hours after chalk deployment, but with no further chalk amendment. Both of these experiments were in the Gulf of Maine. Experiments 4 and 5 were done at the Southern site, similarly to experiments 1 and 2, respectively. The exponential increase in particle size measured with the laser particle counter is consistent with flocculation theory. Our experiments on particle flocculation were designed to estimate the flocculation efficiency of particles, and were predicated on the assumption that volume is conserved during aggregation. In such case, the slopes of the particle size spectra should decrease with time, the width of the spectra should increase with time, but the intercepts should remain constant with time. Indeed, we observed a decrease of the particle spectra with time, and an increase in their width. However, it is evident that volume was not conserved during the incubations since the Y-intersect of the spectra increased with time. Two possible explanations account for the lack of volume conservation in the incubations. One is that aggregates were fractal. The other is that new particles were formed during the incubations, either from bacterial or phytoplankton growth, or from aggregation of colloids that are smaller than the detection limit of the laser counter. We hope to be address this latter hypothesis by relating our results to the DOM drawdown observed during the study. J. Goes is currently processing the DOM data from the cruise.
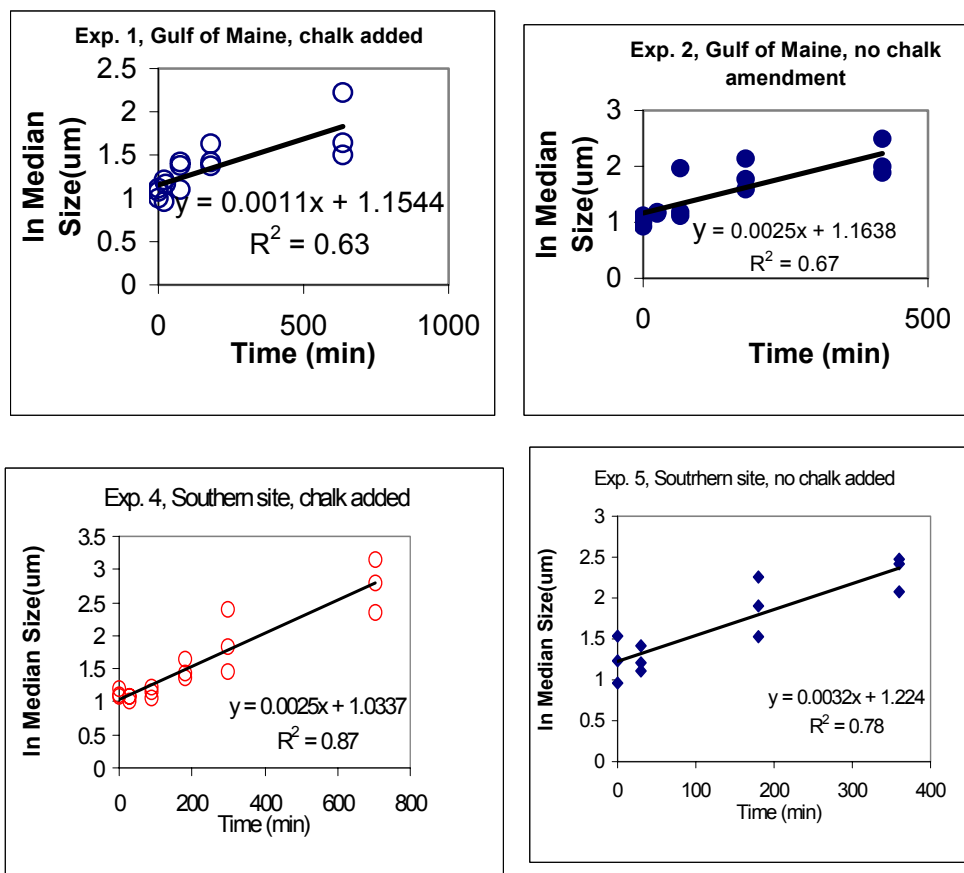
Figure 3. Examples of results (experiments 1, 2, 4 and 5) of particle flocculation experiments in the Gulf of Maine (top two panels) and the Southern station (bottom two panels). The exponential increase with time in particle size in all experiments is consistent with the hypothesis of particle aggregation.
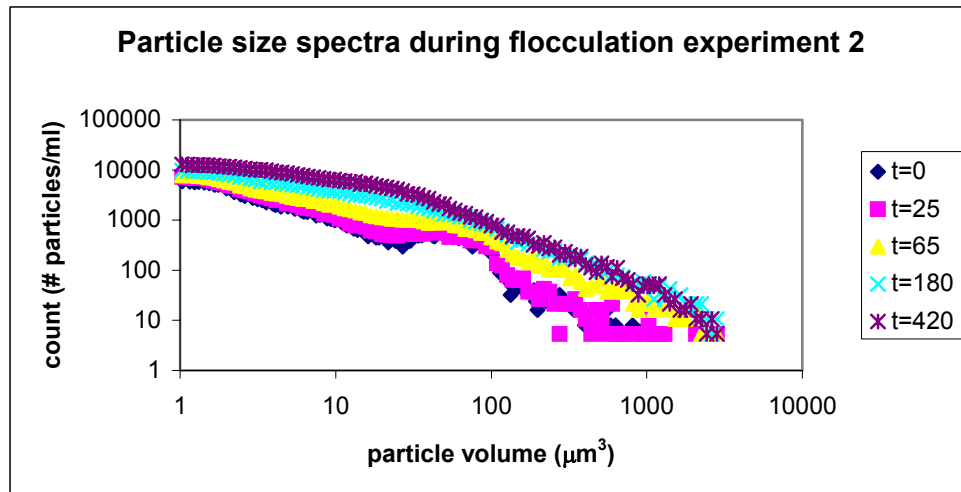
Figure 4. Mean particle volume (X-axis, expressed as cubic microns) versus particle abundance for each size fraction (Y-axis, expressed as particles/ml) as a function of time in minutes (curves of different colors) during flocculation experiment 2. The decrease in slopes and the increase in the range of particle sizes observed with increasing time are consistent with the hypothesis of aggregate formation. The increase in the magnitude of the Y-intersect of the curves with increasing time indicates that total particle volume is not conserved during the experiment.

IMPACT/APPLICATIONS

Our experiments are designed to identify the relative importance of two loss terms—grazing and aggregation—on the mass balance of coccoliths, an important group of optically active particles. Without this information the evolution of the underwater field and prediction of underwater visibility on the spatial (1-10,000m horizontal and 1-100 m vertical) and temporal scales (hours to days) of coccolithophore blooms is severely hindered.

RELATED PROJECTS

We work as a part of a team with the other PI's in this project: W. Balch (http://www.bigelow.org/pi/Balch.html), C. Pilskaln (http://www.bigelow.org/pi/pilskaln.html) and J. Goes (http://www.bigelow.org/pi/goes.html), all at Bigelow Lab. For Ocean Sciences, And A. Plueddemann (http://www.whoi.edu/WHOI/SciTechDir/albert_j_plueddemann.html), at WHOI.

REFERENCES

Balch, W.M., Plueddemann, A.J., Pilskaln, C.H., Dam, H.G., McManus, G.B., Goes, J.I. 2002. Chalk-Ex: An Ocean Optics Manipulation Experiment on the Fate of Calcite Particles. Poster presentation, Fall Meeting, Amer. Geophys. Union, San Francisco, 6-10 Dec.

Calbet, A. and M.R. Landry (1999) Mesozooplankton influences on the microbial food web: direct and indirect trophic interactions in the oligotrophic open ocean Limnol. Oceanogr. 44: 1370-1380.

Dam, H.G. and D.T. Drapeau. 1995. Coagulation efficiency, organic-matter glues and dynamics of particles during a phytoplankton bloom in a mesocosm study. Deep-Sea Res. II. 42: 111-123.

Dam, H.G., Pilskaln, C.H., and Smith, A.N. 2002. Aggregation and downward export of particles during Chalk-Ex 2001. Poster presentation, Fall Meeting, Amer. Geophys. Union, San Francisco, 6-10 Dec.

Drapeau, D.T., H.G. Dam and G. Grenier. 1994. An improved flocculator design for use in particle aggregation experiments. Limnol. Oceanogr. 39: 723-729.

McManus, G.B., Dam, H.G. and Smith, A.N. 2002. Biological removal of particles during Chal-Ex: Results of shipboard bottle experiments. Poster presentation, Fall Meeting, Amer. Geophys. Union, San Francisco, 6-10 Dec.